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Abstract

The relation between export behaviour and the propensity to innovate is an important question for a developing economy. This article dedicated to this question through the analysis of the first innovation survey of Tunisian firms. We analyze the relationship between the export behaviour and the innovation propensity of the firms as it can be qualified using econometric estimations (mainly probit models) and non-parametrical regression trees on the results of the first community innovation survey in Tunisia. Our results show that firms that address both the domestic and foreign demands (partial-exporters) have the highest propensity to innovate, and they better benefit from external knowledge sources, as well as a diversified demand. We find that external knowledge sources, internal R&D efforts and some types of cooperative agreements are complementary for product innovations, but the first play an essential role, in the sense that firms must benefit from at least one external knowledge source to attain a significant innovation propensity. We show that innovation behaviour of three subsets of firms are strongly contrasted: pure exporters who only address the foreign demand, pure domestic firms, and partial exporters.

Keywords: Innovation; exports; openness; development; absorptive capacity
JEL codes: O120; O300

1 Introduction

This article analyses the link between export behaviour and the propensity to innovate of firms in Tunisia. Cooper (1994) clearly explains why the shift from import-substituting industrialization to more open-economy models for development, has given a central role to innovative activities of firms in developing countries and why innovation studies can guide industrialization policies in developing countries. Indeed, international competition forces domestic firms of these countries to pay a special attention to their innovative and absorptive capacities.

> "As far as import-substituting economies were concerned, the shift towards open-economy industrialization and export orientation radically changed the terms of reference for technology policies, and added new relevance to the findings of innovation studies in the industrial economies. [...] As far as industries in developing countries are concerned, the need to confront innovative competition and the capabilities required to sustain it has become more pressing because of [...] a shift away from import-substituting and other closed-economy approaches [...] towards industrialization with a more open-economy emphasis, including export promotion". p. 25,31 in (Cooper 1994)

Moreover, these firms continue to count on low labour costs and imitation of foreign technology to sustain their competitiveness in a strong international price competition, despite their technological disadvantage (Porter & Stern 2003). Given that these countries try to export using relatively older products and processes, they need to seek other types of advantages in order to maintain their position in international markets. Strategies based on cost reduction and niche-market exploitation are not sufficient for maintaining their competitiveness since many countries are competing now in these niches, where the residual demand for rather old products is already weak. Consequently, the desire to access to external markets can be a strong motivation for developing innovative activities.

In other respects, recent analyses emphasized that access to foreign markets and, more generally, openness, can also constitute an important channel through which developing countries can effectively access to the international pool of technologies, and, more generally, to external knowledge sources. As such, openness can play a complementary role in the process of economic and technological development, and understanding the conditions under which trade openness can (or cannot) contribute to technological innovation in developing countries hence plays a crucial role in policy-making.

Another important source of motivation for innovative activities, connected with exports, is the market demand. The access to foreign markets indeed constitutes an important demand source for firms, especially in developing countries where the domestic purchasing power and demand can be considerably weak and fragile in comparison with the markets for exports (notably the demand from the consumers of industrialized countries). Of course, the instability of international markets and of exchange rates can fragilize, in its turn, firms that become exclusively dependent on this demand. But, being able to face such an uncertainty, and to survive under it, can necessitate again

some capacity to innovate, at least in processes, in order to be able to lower costs under unfavourable competitive circumstances. But, another ability, the capacity to serve a heterogeneous demand taking its source in both foreign and domestic markets can also constitute an important impulse to innovate: in processes for coping with the lower domestic purchasing power and higher quality standards of foreign markets; in products for adapting to the specific needs of the domestic market, and demands of foreign markets. Consequently, firms serving both foreign and domestic markets can have motivations different than the ones of the firms exclusively dedicated to exports. The analysis of this potential heterogeneity in behaviour will play a central role in this article.

We must also take into account, in our approach, that analysing the relationship between innovations and exports can be quite complex, since the results can suffer from a self-selection bias due to the fact that innovating firms can more easily face international competition[1]. The "flying geese" paradigm (Akamatsu 1961), used to describe the alignment of countries along the different stages of development, shows a close link between technological development and related changes in the export structure and the pattern of foreign direct investments. In this flying geese model for international division of labour, developing countries are involved in a multi-layered catching up process of industrialization in line with comparative advantage (Dowlinga & Cheang 2000).

More specifically for the case of Tunisia, the issue of innovation and exports is particularly important, since the Tunisian public policies in the recent period have been quite remarkable in their ambition to increase the innovative capacity and the competitiveness of domestic firms, while they opened the domestic market to foreign firms, mainly through the accession to the GATT, and the establishment of the free trade union with European Union (1995). This ambitions has taken a more deliberate form as the first law on research and technological development in 1996 (extending the *Mise à niveau* - upgrade - program started in 1995, mainly focused on industrial competitiveness). This law aims to improve the participation of private firms, organisation to research and technological development, to foster the coordination of different components of the national innovation system, to facilitate technology transfers towards Tunisian firms, and to promote innovative activities through partnerships between firms and research structures.

An important dimension of these policies has been the creation of technical agencies and other public organisms that aims to helps the development of technological competencies of domestic firms. Since these firms are mainly technological followers, more than leaders, this development consists in the increase of their absorptive capacity (Cohen & Levinthal (1990)). Given these efforts, we will dedicate a special attention to the role that these organisations may play in the innovativeness of exporting firms (Rahmouni et al. 2010, Fabrizio 2009, Cassiman & Veugelers 2006, 2004).

Since 1970s, the Tunisian government has encouraged the development of exporting industries, and created an off-shore regime to attract foreign direct investments oriented to these industries. This investment has taken the usual forms of delocalisation by foreign firms, and international subcontracting. The latter has considerably expanded over the

[1]Any result on this connection must be taken with some caution Mohnen et al. (2006), especially because of the simultaneity of the answers in the surveys on these points.

last two decades, and became a central component of the export-oriented development strategy adopted by Tunisia. The issue of the innovativeness of subcontractors leads to important questions on the relevance of this strategy and its rationale for the future, especially now that Tunisian institutions will live through new opportunities and choices. For example, subcontracting may create a strong foreign dependence, without developing a sufficient technical knowledge stock in the domestic market. Indeed, the production in these export oriented industries often requires foreign technical assistance, and the technologies used by them are in general developed by the foreign firms the provide the equipments, install the materials and train the staff and the technicians. Under these conditions, domestic firms may not be able to acquire the competencies that are necessary in the adaptation of foreign technologies to domestic needs and in the development of new production equipments. In fact, the expansion of subcontracting in Tunisia is mainly characterized by the creation of plants with low-technical progress, and the exploitation of advantages related to low labour costs. These strategies do not seem very favourable to the technical independence of domestic firms[2]. Consequently, the final effect on the innovativeness of the exporting firms merits a careful statistical and econometric analysis that we propose to carry out in this article.

This article studies the innovation propensity of firms with different export behaviour in Tunisia. It develops, on this specific issue, the more general results discussed in Rahmouni et al. (2010). As the latter, this study will be based on the first innovation survey carried out in Tunisia in 2005, by the Ministry of Scientific Research, Technology and Competency Development (MSRTCD)[3]. This survey constitutes a first photography of the consequences of the development strategy followed in the last two decades in Tunisia. Rahmouni et al. (2010) show that the main favourable characteristics of the innovating firms are the existence of an internal R&D unit (for product innovations) and size (for process innovations, measured as the logarithm of sales, as in this article), as well as the capacity to benefit from complementary external knowledge channels. Two paradoxical results of this analysis were the negative link with the participation of state and the insignificant link with export ratio of the sales. The clarification of the latter result is the motivation of this article. Already in Rahmouni et al. (2010), we showed that addressing multi-markets was positively linked to innovativeness. We explore in this article the mechanisms that are behind this link, by comparing the characteristics and the behaviour three classes of firms with different export behaviour.

In our approach, we will take into account two important modulations of the concepts and results developed for industrial countries, necessary when we adapt these concepts to the context of a developing country. First, we can expect a balance between the characteristics of innovating firms quite different from the one observed in the innovation studies that are based on formal R&D investments of firms (*see* also Bell & Pavitt (1993)

[2]The indicator of technological development defined according to the classification of the United Nations Development Program (UNDP 2001) shows that Tunisian exports are characterized by low-technology contents (52% of exports of goods). But, the technology achievement index (TAI) given in Table 11 of the Appendix A.1 shows that Tunisia is among dynamic adopters of new technologies.

[3]This survey is based on the well known CIS methodology. The authors are very grateful to Hatem Mhenni, National Observatory of Science and Technology, for providing the data.

and the Bogotá Manual, Jaramillo et al. (2001)). Second, we observe that in developing economies all firms cannot necessarily develop completely new and better products or production processes for the market. Many innovations simply consist in introducing better products that are new only for the Tunisian firms, without being new at the international level. Thus, our analysis must not be restricted to the group of firms that undertake formal R&D activities, but cover all firms that rely on the introduction of novelty to face the market competition and demand. This more broad definition of innovations is also adopted by other studies on developing countries (*see,* for example, Almeida & Fernandes (2008) or Kannebley et al. (2005)).

The paper is structured as follows. Section 2 discuss main results obtained in the recent literature on the links between export behaviour and innovativeness. This literature seems to indicate a rather robust positive link between these activities. Section 3 presents the data set used in this work, and our research methodology. Section 4 studies the relationship between export behaviour and innovativeness of firms. First, we distinguish innovative behaviour of three sets of firms: firms that export the totality of their production; firms that serve only the domestic market; firms that serve both foreign and domestic markets. We also distinguish product and process innovation behaviours. Our results show that the firms that serve both markets have the highest propensity to innovate. We analyze the determinants of this result that is rather paradoxical in comparison with the conclusions of the literature discussed in the second section. The last section concludes the paper.

2 Export behaviour and innovation: Discussion of the literature

The relationship between exports and innovation activities has been widely studied by the endogenous growth and the new trade theories which distinguish between the role of knowledge spillovers generated either by the interactions with foreign agents (Grossman & Helpman 1991, Rivera-Batiz & Romer 1991*a*,*b*), or by the use of the intermediate goods (Rivera-Batiz & Romer 1991*a*,*b*, Coe & Helpman 1995). Another channel analysed in the literature concerns the role of the international trade on incentives to invest in R&D and innovation activities (Aghion & Howitt 1998). The theory of internalization asserts that firms may acquire technologies and increase their innovative capacities through their access to foreign markets. Exports are indeed considered as the most prevalent form of international expansion. However, the analyses are carried out mainly at the macroeconomic level, and they do not help to explain heterogeneity in firms behaviour. The relationship between exports and innovation may also be affected by the degree of market competition that the firms face. Aghion et al. (2005) show an inverted-U shaped link between competition and innovation. Two tendencies interact to form the shape of this link. On one hand, product differentiation and innovation increase with competition (Shaked & Sutton 1987). On the other hand, innovations may decline with competition, because the later reduces monopoly rents that motivate the innovations (Aghion & Howitt 1992). As a consequence, the role of foreign competition is not clear-cut (see also Piva

& Vivarelli (2007)).

Given the narrowness of the Tunisian market, the enlarging of the market through exports may also allow for higher investment levels and easier adoption of foreign technologies. In other respects, the opening that followed the participation to the GATT, and the free trade agreement with European Union, has also increased the heterogeneity of the demand addressed by domestic firms. A higher competition by foreign firms has also resulted from this opening. In such a context, Tunisian firms must innovate in order to be able to serve both domestic and foreign demands in order to attain satisfactory profit levels, and, even more dramatically, to survive. Previous empirical studies have tested the demand-pull hypothesis and found that innovation may indeed be driven by output (Piva & Vivarelli 2007) and by changes in market conditions (Nemet 2009). They have also established that geographic differences in the acceptance of products, and in the composition of demand (Griliches 1957, 1960), shifts in relative factor prices (Hicks 1932), and, finally, potential new markets (Vernon 1966) may largely influence the innovative behaviour of firms.

The foreign demand[4] for the products of the Tunisian firms is characterized by a higher growth rate in comparison with the domestic demand. But, Tunisian exports are strongly concentrated on a limited number of products and European countries where they are confronted with a strong competition from Asia and Eastern Europe. Firms in these regions benefit from lower labour costs and stronger productivity. Tunisian firms hence are incited to increase their competitiveness. The openness consequently reinforces the need for process innovation, and for a better adaptation of products to foreign and domestic demands (Piva & Vivarelli 2007).

Theoretical literature seems to point to a positive link between export behaviour and innovativeness of firms. We can confront these results to the existing empirical literature. Although several empirical micro-level studies emphasized the selection effects of more productive firms into export markets, recent studies (see Table 1) assert that access to foreign markets is positively related with innovativeness (Harris (1991), Alvarez & Lopez (2005), Costantini & Melitz (2008)). They also recognize that firms jointly make innovation and export market participation decisions (Aw et al. 2007, Bustos 2010, 2007, Verhoogen 2008).

Another channel considered by several studies is the ability of the exporters to tap foreign knowledge bases, which are not available in the domestic market or for foreign direct investments. Exporting may hence induce a flow of information and knowledge through interactions with foreign parties such as buyers, suppliers, intermediaries and competitors (Bratti & Felice 2009). This acquired knowledge may then spill back on the local firms (*Learning by exporting*, Salomon & Shaver (2005)). Salomon (2006) concludes that exports provide Spanish firms with exposure to diversified knowledge inputs located in foreign markets, with an emphasis on developed countries. Firms can also acquire new knowledge through export intermediaries, joint-venture partners and trade associations

[4]The contribution of foreign demand increased by 2.2% during the 9^{th} Development Plan (1997-2001) and 1.6% during the 8^{th} one (Tunisian Institute of Competitiveness and the Quantitative Studies, ITCEQ 2004).

(Kogut & Chang (1991)), or directly from customers who suggest specific improvements that stimulate innovation (von Hippel (1988)). Indeed, customers from different nations do not share identical tastes. The products desired by foreign customers may thus differ from those offered in domestic market, leading firms in developing countries to upgrade their technologies.

Only a small subset of studies that use micro level data explore the relationship between openness and technological innovation in developing countries (see, for example, Alvarez & Robertson (2004)). For Alvarez (2001), Alvarez & Robertson (2004), Alvarez & Lopez (2005), export is the most significant external source that significantly increases technological innovation. For Brazilian firms, Braga & Larry (1991) find that the effect of the export is highly significant and quite large, indicating that the competitive pressure of producing for foreign markets demands greater access to imported technology, encourages technological effort. Almeida & Fernandes (2008) find, for 43 developing countries, a strong positive correlation between trade and technological innovation. The exposure to foreign markets promotes technology adoption, and exporters have a higher likelihood of adopting new technologies than firms oriented exclusively to the domestic market. Trade liberalization also seems to increase exporting revenues, inducing more firms to enter the export markets and to adopt skill-biased new technologies (Bustos 2010, 2007). It may positively affect firm efficiency by stimulating process innovations which make a case in favour of the learning by exporting hypothesis (Damijan et al. 2010).

Table 1: Recent empirical studies on openness, foreign competition and innovation

Authors	**Sample**	**Results**
Almeida & Fernandes (2008)	43 developing countries	Strong positive correlation between trade and technological innovation. The exposure to foreign markets promotes technology adoption, and exporters should be more likely to adopt new technologies than firms selling exclusively to the domestic market. Exporters can learn about new technologies or products through their interaction with more knowledgeable foreign buyers. They may be exposed to more competitive markets and hence be forced to improve their technology.
Alvarez & Lopez (2005)	Chilean firms	Firms may be forced to improve their technological capabilities in order to face strong competition in export market.
Alvarez & Robertson (2004)	Chilean and Mexican surveys	Export is the most significant external source of technological innovation, but FDI also plays an important role.
Alvarez (2001)	Chilean data	Export increases significantly technological innovation which increases the probability of exporting.
Braga & Larry (1991)	Brazilian firms	The effect of the export is highly significant and quite large, evidence that the competitive pressure of producing for foreign markets demands greater access to imported technology, encourages technological effort and increases the utilisation of modern methods of quality control.
Belderbos (2003)	Japanese firms	Firms with substantial overseas sales are more likely to perform R&D abroad in order to keep track of local demand and technological trends, and to provide technical support for marketing and after sales service.
Caselli & Coleman (2001)	Computer-import	The cross-country evidence shows a positive correlation between trade openness and technology adoption.
Damijan et al. (2010)	Slovenian manufacturing firms	Exports increase the probability of becoming a process rather than product innovator. However, there is no empirical support for the hypothesis that either product or process innovations increase the likelihood of becoming an exporter.
Harris (1991)	SPRU data	Export intensity has a positive and significant relationship with innovation.

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... table 1 continued

Lederman & Maloney (2003)	Cross-country data	The cross-country evidence shows a positive correlation between trade openness and R&D investments.
Salomon & Shaver (2005)	Spanish firms	Exporters tend to introduce more new product innovations very quickly after market entry and file for significantly more patents several years after entry into export markets.
Salomon (2006)	Spanish firms	Foreign market contact via exporting provides firms with exposure to diverse knowledge inputs located in foreign markets (and not available in the domestic market). Export strategies employed by the firm influence the flow of that knowledge, and thereby affect innovative productivity.
Velde (2003)	British data	Exposure to foreign competition accelerated the process of the adoption of technology. Firm facing greater foreign competition, whether at home or in a foreign market, is more likely to upgrade its existing technologies or introduce new technologies.
Veugelers & Cassiman (1999)	Belgian firms	Higher export to sales ratio increases the probability of innovating. Competitive pressures in the international markets require constant innovation to sustain participation in such markets.

3 Dataset, model and methodology

We first present the dataset we use in this article. The discussion of the methodology we have adopted is presented in a second paragraph.

3.1 Overview of the dataset

The analysis is based on micro data from the Innovation Survey provided by MSRTCD[5] which surveyed firms about various aspects of their innovation activity from 2002 to 2004. Following the Oslo Manual, a harmonized questionnaire inspired from the Community Innovation Survey (CIS) was used to collect the data. Since the focus is to uncover factors that favour innovation capacity of Tunisian firms, the survey was targeted in a manner to cover the maximum of firms likely to have an innovative and/or R&D activity. The choice of the population was restricted to:

- manufacturing firms with high technological intensity and/or strong added value;
- firms having manpower higher than 10 people;
- firms indexed in the Industry Promotion Agency and the National Institute of the Statistics.

The targeted population includes 900 firms. The confrontation with the national directory of the National Institute of the Statistics leads to release a final list of 739 firms. Among them 586 firms answered the questionnaire with a rate of answer equal to 79%. Table 4 gives the descriptive statistics (the mean and the standard deviation) of the variables used in this article. We also indicate in the table the type of variable: binary or continuous (Table 2).

This survey has many shortcomings. It shares the common deficiencies of the CIS inspired surveys (many qualitative variables, subjective questions difficult to interpret, etc.), but it also has some specific shortcomings: it constitutes just an observation point, any dynamic dimension that would allow panel data analysis; some questions propose items difficult to interpret by the respondents or items that do not belong to the same level of causality (like mixing mid-term strategic dimensions with immediate consequences of decisions). Nevertheless, this survey is precious since it allows an outlook to the innovation process of Tunisian firms.

3.2 Methods of analysis

We use two different statistical methods to analyze the main determinants of innovative activity in Tunisia: Probit models, decomposition analysis and regression trees. In our case, innovation is a binary dependent variable, which is equal to 1 if the firm innovates, or equal to 0 if the firm does not innovate. Probit results indicate the global role of the variables in the explanation of the propensity to innovate. We use non-parametric

[5]MSRTCD: Ministry of Scientific Research, Technology and Competency Development.

Dependent Variables:	
innovprod	Product innovation
innovproc	Process innovation
Independent Variables:	
collInternatOrg	Dummy for collaboration with international organisms
collLabUnit	Dummy for collaboration with laboratories and research units
collNatOrg	Dummy for collaboration with other national organisms
collOtherFirms	Dummy for collaboration with others firms
collRecCent	Dummy for collaboration with research centers
collUniv	Dummy for collaboration with universities
ConsultTechn	Dummy for access to external technical assistance
depRD	Dummy for internal R&D department
multiMarket	Dummy for firms serving both domestic and foreign markets
partForeign	Share of Foreign capital (in percentage)
partState	Share of State in the capital of the firm (in percentage)
Sales	Sales in million dinars

Table 2: Description of the variables used in the analysis

Non exporter	**NE**	Export = 0%
Partial exporter	**PE**	0% < Export < 100%
Exclusive exporter	**EE**	Export = 100%

Table 3: Classification of firm groups following their export ratios

	All firms		**NE**		**PE**		**EE**		***z-test***
Variable	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**comparison**
innovproc	0.49	0.50	0.42	0.50	0.60	0.49	0.43	0.50	$PE > NE = EE$
innovprod	0.41	0.49	0.37	0.48	0.56	0.50	0.29	0.46	$PE > NE = EE$
collInternatOrg	0.13	0.33	0.15	0.35	0.15	0.36	0.10	0.29	$PE > NE = EE$
collLabUnit	0.08	0.27	0.08	0.28	0.13	0.34	0.02	0.15	$PE = NE > EE$
collNatOrg	0.15	0.36	0.15	0.35	0.17	0.38	0.14	0.34	$PE = NE = EE$
collOtherFirms	0.12	0.32	0.12	0.33	0.12	0.33	0.11	0.31	$PE = NE = EE$
collRecCent	0.07	0.26	0.10	0.30	0.08	0.27	0.05	0.21	$PE = NE > EE$
collUniv	0.11	0.31	0.17	0.38	0.14	0.35	0.03	0.18	$PE = NE > EE$
ConsultTechn	0.41	0.49	0.41	0.49	0.56	0.50	0.27	0.45	$PE > NE > EE$
depRD	0.54	0.50	0.51	0.50	0.68	0.47	0.43	0.50	$PE > NE = EE$
lnSales (*)	15.29	1.76	15.35	2.11	15.92	1.55	14.61	1.47	$PE > NE > EE$
partState (*)	7.17	25.09	19.95	38.76	4.17	19.41	0.90	9.49	$NE > PE > EE$
Observations	586		157		208		221		

Table 4: Summary of dataset variables. The table gives the mean and the standard deviation of each variable. All variables are binary except when signalled by (*) for continuous variables. NE: no export, PE: partial exporter, EE: exclusively exporter. $z-test$ of proportion differences between groups for binary variables and mean-comparison $t-test$ for continuous ones (WMW-test comparison of the medians gives the same results for continuous variables *lnSales* and *partState*.)

regression trees to partition our observation space in order to analyze the interaction between variables and the possible complementary or substitutable relationships between them. The gap in the innovativeness between different groups of firms (Table 3) and the weakness of EE ones are analysed in more details using regression trees and non-linear decomposition analysis for Probit regressions.

3.2.1 Decomposition analysis

The Decomposition techniques for Probit models are used to partition the difference in mean responses between the groups of firms (the difference in the propensity to innovate between NE, PE and EE firms) into components that reflect the difference in the mean levels of model predictors and difference in the effects of those predictors across groups. The multivariate decomposition approach is the most familiar and widely used method for linear models developed by Blinder (1973) and Oaxaca (1973). The differences in the innovativeness between two groups is decomposed into a part that is explained by differences in observed characteristics or endowments across groups and a part attributable to differences in the estimated coefficients (the effects of the characteristics of groups). This kind of decomposition of the innovativeness differential between groups of firms is familiar from other areas in economics. While the Blinder-Oaxaca decomposition technique is easy to apply if the outcome variable is continuous, a problem arises if the outcome is binary and the coefficients are from a non-linear probit model because these coefficients cannot be used directly in the standard Blinder-Oaxaca decomposition equations (Fairlie 1999, 2005, Fairlie & Robb 2007). Therefore, Fairlie (1999, 2005) introduced a decomposition method for models with binary dependent variables that uses estimates from a probit model. The goal of the decomposition is to partition a difference in mean values between two groups into components owing to group differences in observed characteristics, and to group differences in the estimated effects of those characteristics based on the Probit model. Multivariate decomposition provides more detail by assessing the relative contribution of specific covariates to these components. It explains the gap in the average probability of the binary variable between two groups. The gap is decomposed into a part that is due to group differences in the magnitudes of the determinants of the outcome in question, on the one hand, and group differences in the effects of these determinants, on the other. This approach helps us to understand the reason of the innovativeness differences revealed in the descriptive statistics and probit analysis. It provides a detailed descriptive picture of these differences between groups of firms.

3.2.2 Regression trees

Non-parametric regression trees are useful for detecting important variables, interactions and identifying outliers. They are also very useful as an exploratory tool for analyzing the interaction between explanatory variables of a model. A regression tree (Venables & Ripley (1999), chap10) establishes a hierarchy between independent variables using their contribution to the overall fit of the regression. More exactly, it splits the set of observations in sub-classes characterized by their values in terms of their contribution to

the overall fit and of their predictions for the dependent variables. This value is validated against a fraction (10%) of the sample that is not used in the estimation. The value at which this partitioning is stopped (and the tree cut) is given by the complexity parameter (cp). Regression trees are very flexible and powerful in the clarification of the structure of the observations. The tree gives a hierarchical sequence of conditions on the independent variables of the model: the higher the role of a condition in the classification of the observed cases, the higher its status on the tree. For each condition, the left branch gives the cases for which the condition is true and the right branch gives the cases that are compatible with the complementary condition.

We complete the estimation process by using some descriptive statistical tools such as $z - test$ to compare proportion differences between groups for binary variables and $t - test$ mean-comparison for continuous ones. We use also the two-sample Wilcoxon and Mann-Whitney rank-sum (WMW) test to compare the propensity to innovate between the three groups of firms.

4 Results

We first compare the propensity to innovate of three sets of firms: exclusive exporters **(EE)** that export the totality of their production, non-exporters **(NE)** that are totally dedicated to the domestic market and partial exporters **(PE)** that serve both markets. This comparison (*see* Table 4, last column) clearly shows that the partial exporters have the highest propensity to innovate, both for product and process innovations. We therefore analyze, in a second paragraph, the conditions under which NE and EE firms have the lowest innovativeness, and lag behind partial exporters. The last paragraph analyzes the characteristics of the firms, in each subset, with the highest propensities to innovate in order to complete our analysis.

4.1 Export behaviour and propensity to innovate

Rahmouni et al. (2010) show that exclusively-exporting firms exhibit lower innovation propensity. Indeed, even if the inequality in the distribution of revenues is relatively moderate in Tunisia in comparison with other developing countries, firms addressing the domestic demand may face a strong heterogeneity, and serving a heterogeneous demand can require the creation of new and diversified products.

We start from the observations of the preceding sections (theoretical discussions and shortcomings of our database) to formulate our econometric model. To answer our research questions, we use a probit model in which the probability of innovation is conditional to the variables given in the following list. As in Rahmouni et al. (2010), we also indicate the corresponding expected sign of each variable's influence:

- Existence of a R&D department ($depRD$, +);
- Sales of the firm representing its size on the market ($log(Sales)$, +);

	Prod. Innov.				Proc. Innov.			
	All	**NE**	**PE**	**EE**	**All**	**NE**	**PE**	**EE**
R&D dept.	**0.52**	0.49	0.14	**0.72**	0.24	0.05	0.23	0.28
	(4.04)	(1.60)	(0.63)	(3.49)	(1.92)	(0.17)	(1.12)	(1.40)
log(Sales)	**0.10**	**0.19**	0.06	−0.01	**0.13**	**0.21**	0.06	**0.15**
	(2.73)	(2.50)	(0.85)	(−0.08)	(3.64)	(3.03)	(0.87)	(2.06)
partState	**−0.01**	**−0.01**	**−0.02**	−0.0	**−0.01**	−0.01	**−0.01**	−0.01
	(−4.10)	(−2.45)	(−3.11)	(−0.01)	(−2.79)	(−1.41)	(−2.10)	(−0.62)
collUniv.	**0.57**	**0.84**	0.35	0.98	0.24	−0.30	**0.73**	0.55
	(2.62)	(2.18)	(1.12)	(0.15)	(1.14)	(−0.78)	(2.16)	(0.80)
collRecCent	−0.28	−0.05	−0.54	−0.10	−0.12	0.43	−0.58	−0.34
	(−1.03)	(−0.10)	(−1.28)	(−0.16)	(−0.46)	(0.85)	(−1.48)	(−0.63)
collLabUnit	−0.20	**−1.57**	0.24	−0.15	−0.35	−0.18	−0.42	−0.70
	(−0.84)	(−2.37)	(0.73)	(−0.20)	(−1.54)	(−0.33)	(−1.40)	(−0.90)
collNatOrg	0.25	0.30	0.22	0.34	**0.51**	0.11	0.21	**0.87**
	(1.49)	(0.72)	(0.78)	(1.21)	(2.97)	(0.29)	(0.74)	(3.01)
collInternatOrg	**0.86**	0.26	**1.37**	**1.01**	**0.57**	0.11	**1.12**	0.35
	(4.29)	(0.66)	(3.42)	(2.78)	(2.85)	(0.26)	(3.08)	(0.94)
collOtherFirms	0.28	0.12	0.40	0.19	0.30	0.66	−0.10	0.56
	(1.47)	(0.26)	(1.26)	(0.59)	(1.60)	(1.30)	(−0.34)	(1.74)
ConsultTechn	**0.54**	0.43	**0.74**	0.33	**0.65**	**1.13**	**0.64**	**0.53**
	(4.30)	(1.48)	(3.65)	(1.47)	(5.27)	(3.89)	(3.18)	(2.39)
constant	**−2.48**	**−3.71**	−1.49	−1.05	**−2.53**	**−3.81**	−1.27	**−2.77**
	(−4.24)	(−3.18)	(−1.34)	(−0.95)	(−4.62)	(−3.63)	(−1.20)	(−2.64)
Observations	538	126	208	204	538	126	208	204
LR $\chi^2(10)$	134.35	36.42	53.50	42.32	110.33	38.16	41.09	39.74
Prob $> \chi^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.18	0.22	0.19	0.17	0.15	0.22	0.15	0.14
Predict Prob.	0.40	0.29	**0.59**	0.28	0.50	0.42	**0.63**	0.43

The $z - values$ are given below coefficients, between parentheses.

Table 5: Results of the probit estimations for different group of firms

- Participation of the State in the capital of the firm ($partState$, $\pm$);
- Channels of external technical knowledge (+):
  - universities ($collUniv$);
  - research centers ($collRecCent$);
  - laboratories and research units ($collLabUnit$);
  - national organisms ($collNatOrg$);
  - international organisms ($collInternatOrg$);
  - other firms ($collOtherFirms$);
  - external technical assistance ($ConsultTechn$).

Table 5 gives the results of the probit estimations for the determinants of the product and process innovation success for each group of firms: NE, PE and EE firms (Table 3). The coefficients that are significant for $\alpha \leq 5\%$, are given in bold characters. Table 6 gives the marginal effects of significant variables. We examine and compare here the global determinants of the propensity to innovate for these three types of firms. The results reveal a number of specific differences between these three subgroups regarding the statistical significance of the relationship between the explanatory variables and the propensity to innovate, and also regarding the size of these effects.

The predicted probabilities show that the NE et EE firms are poor innovators (*see* Table 5). The WMW-test used to compare predicted probabilities also show that PE firms are likely to be more innovative (in product and process innovations) than EE and NE ones (*see* Table 4). The results from the predicted probability row in Table 5 and the comparisons of predicted probabilities of innovation through WMW tests in Appendix A.2 can be summarized in the following proposition:

Proposition 1 *The most innovative firms (for both types of innovation) are not the ones totally dedicated to exports but the ones that serve both the foreign and domestic markets. Partial-exporters have indeed the highest propensity to innovate.*

We use the global results of probit estimations and their corresponding marginal effects to analyse the predominant covariates associated to product and process innovations for these three types of firms.

The factors related to **product innovations** at a global level are (*see* the second column of Table 5): internal R&D, firm size, State participation in the firm (with negative sign), and the collaboration with universities, international organisms (for all types of firms), and recourse to technical consulting organisms. However, the determinants are quite contrasted between the subgroups of firms: the internal R&D plays a role only for the innovations of the exclusively-exporting firms (*see* also Rahmouni et al. (2010)); the firm size and the collaboration with universities and research laboratories only have dominant effects for exclusively-domestic firms ; the access to help from technical consulting organisms only plays a role for partially-exporting ones. Firms adressing a diversified

	Prod. Innov.				Proc. Innov.			
	All	**NE**	**PE**	**EE**	**All**	**NE**	**PE**	**EE**
R&D dept.	0.20			0.25				
log(Sales)	0.04	0.06			0.05	0.08		0.06
partState	-0.01	-0.004	-0.008		-0.003		-0.004	
collUniv.	0.22	0.31					0.24	
collRecCent								
collLabUnit		-0.32						
collNatOrg					0.20			0.33
collInternatOrg	0.33		0.41	0.38	0.22		0.33	
collOtherFirms								
ConsultTechn	0.21		0.28		0.26	0.42	0.24	0.21
Predict Prob.	0.40	0.29	**0.59**	0.28	0.50	0.42	**0.63**	0.43

Table 6: Marginal effects of the statistically significative variables for different groups of firms

market take advantage from both the possibility of risk-sharing over different markets and from the internalization of possible inter-product positive innovation spillovers (Piva & Vivarelli 2007). Moreover, the participation of State in the capital of the firm plays a negative role only for partially-exporting or exclusively-domestic firms: being completely dedicated to foreign markets seems to protect firms from this negative influence. Technical information received from international organisms and help from technical consulting organisms plays also a role for partially- and exclusively-exporting firms. Large NE firms are less financially constrained regarding their possibility to share costs and risks over a large amount of output (Cohen & Klepper 1996). The generally limited size of domestic market limits the possibility to take advantage of benefits of economies of scale and competition-driven productivity gains.

The factors related to **process innovations** at a global level are (*see* the sixth column of Table 5): firm size, State participation in the firm, collaborations with national organisms, access to external technical assistance and technical information received from international organisms. External knowledge sources play a less contrasted role in this case: while collaborations with universities and international organisms are necessary for partial exporters, and collaborations with national organisms are only beneficial for exclusively-exporting firms, all types of firms benefit from technical consulting agencies (*see* below a more detailed discussion of the respective roles of these sources). We observe that higher sales are positively correlated with process innovations for exclusively-exporting and exclusively-domestic firms. The State participation plays a negative role only for the partial exporters (but this effect is enough robust to be globally significative).

The main results established above are summarized in the following propositions.

Proposition 2 *The highest innovative capacity of the partial exporters comes from their collaborations with technical consulting agencies, universities and international organisms.*

This observation again underlines the essential role played by external knowledge sources (Rahmouni et al. 2010).

Proposition 3 *The usual narrowness of the domestic market limits the possibility to take advantage of economies of scale and competition is mainly driven by productivity gains. The success of innovations is based on both export– and domestic–market–oriented strategy.*

We will now analyze more in detail the differences in the propensity to innovate of different subgroups.

The coefficient estimates of the probit regression models give us a good overview of the relative weight of the different independent variables. However, not only the estimated coefficients linking independent variables to the probability of innovation can differ between different types of firms, the composition of the dataset with regard to these variables (characteristics of the firms) may also differ. The last column of Table 4 indicates that such a heterogeneity is indeed can be observed for the independent variables between these three subgroups. It would be interesting to check whether and to which degree this heterogeneity of factors contribute to the differences in the propensity to innovate between the subgroups.

To answer this question we must decompose the total effect of the covariates and compute the share that reflects the differences in coefficients linking these factors to the probability of innovation. The complementary share would then indicate the differences in the characteristics of the firms, or in other unobserved and unmeasurable factors. In order to achieve this, we apply the non-linear decomposition technique described in Section 3.2.1. The gap in the innovativeness can hence be decomposed in two parts: the differences in the way the independent variables operate for both groups (i.e. the effects of the independent variables), and the group differences in characteristics with respect to other unobserved factors. We also resort to regression trees, to better understand the interaction between characteristics and to check the possible complementarity or substitutability that can exist between them in the realization of the innovations. The next section will present this analysis.

4.2 Determinants of differences in propensities to innovate

The last part of Proposition 1 can be analyzed in more details using the non-linear decomposition technique.Given the differences between the subgroups of firms in our sample, in observed characteristics and the regression coefficients, the question arises to on extent the differences of the innovation behaviour across firms can be explained by differences in characteristics of the firms on the one hand, and by differences in the coefficients on the other. The total contribution of group differences in characteristics effect identified in the decomposition represents the part of the difference in the propensity to innovate that is due to observed differences over groups in the explanatory variables. The residual effect not only represents the part due to different regression coefficients, but also captures the proportion of the difference in density due to group differences in unmeasurable or unobserved factors. This technique helps us to tackle the question on how high would the share of innovators among EE firms (or NE firms) be, if the PE firms were among the group of EE firms (or NE firms). In other words, how high would the

	Product Innovation				Process Innovation			
	PE vs EE		PE vs NE		PE vs EE		PE vs NE	
Reference Group	**PE**	**EE**	**PE**	**NE**	**PE**	**EE**	**PE**	**NE**
P(innovate=1/Group)	0.563	0.304	0.563	0.341	0.601	0.436	0.601	0.429
Differential gap	0.259	-0.259	0.221	-0.221	0.165	-0.165	0.172	-0.172
characteristics effects	0.135	-0.139	0.145	-0.104	0.123	-0.140	0.116	-0.129
Contribution in percent	52.32%	53.79%	65.54%	47.01%	74.76%	85.22%	67.44%	74.74%
Residual effects	0.123	-0.119	0.076	-0.117	0.042	-0.024	0.056	-0.044
Contribution in percent	47.68%	46.21%	34.46%	52.99%	25.24%	14.78%	32.56%	25.26%
Detailed decomposition								
depRD		-24.83%						
lnSales				-14.55%		-40.38%		-22.86%
partState	-5.68%		22.78%	-19.12%	-6.68%		27.79%	
collUniv					15.12%			
collRecCent								
collLabUnit				9.00%				
collNatOrg								
collInternatOrg	8.74%	-9.05%	3.30%		8.80%			
collOtherfirms								
ConsultTechn	29.04%		23.64%		40.14%	-34.25%	23.09%	-36.25%

The last part reports only significant contribution estimates at 5% level. Contribution estimates given in percent of the gap of mean values of the decomposition using 100 replications (Fairlie 2005).

Table 7: Decomposition analysis of the consequences of export behaviour on innovation propensity

propensity to innovate of EE firms (NE firms) be, if the characteristics of the PE firms were linked to the probability of innovation according to the coefficients estimated using the EE sample (NE sample). The results obtained with the decomposition approach are given in Table 7.

Moreover, we can also check when the EE and NE firms are particularly weak on innovations. We detect these configurations using regression trees that give a partitioning of our observations on the basis of the expected value of the innovation success.

Even if we give the results both for the EE and NE firms, our discussion will be exclusively focused on the case of the EE firms, given the dedication of several incentive programs to these firms in Tunisia.

The decomposition of the **product innovativeness** between PE and EE firms is analyzed in the second column of Table 7. Each subgroup can be used as the reference group, and the results usually differ according to the choice of the reference group (the technique used is presented in detail in the preceding section).

The differential gap in the rate of product innovation between the PE and EE firms is about 25.9% ($= 0.563 - 0.304$). Overall, total contribution of group differences in the average values of the independent variables account for about 52.32% of the differential gap when the sample of PE firms is used in order to calculate the coefficients which are the basis of the decomposition. This means that difference between PE and EE firms is mainly due to difference in observable characteristics rather than in the estimated coefficients and hence in the innovation behaviour. The other 47.68% are due to the differences in the coefficient effects and also to the unobserved or unexplained factors.

The contribution of each variable to the gap is equal to the change in the average predicted probability from replacing EE firm distribution with the PE firm distribution of that variable, while holding of other variables constant (see the bottom half of Table 7). The large difference in the share of product innovators between PE and EE firms can be explained by the higher intensity of access to external technical assistance and collaboration with international organisms for PE firms (first column) and also by the insufficient internal R&D department proportion for EE firms, which confirms the descriptive evidence given in Table 4 and results from the regression trees (see below). This result shows that the profile of Tunisian firms can be contrasted with other developing countries. Indeed, one would think, that EE firms could better benefit from external technical assistance and collaborations with international organisms[6].

The results for the configurations corresponding to the weakest innovativeness in the regression trees (*see* Figures 1, 2, 3 and 4) are summarized in Table 8.

We observe that EE firms the most deficient in product innovations, when they do not benefit from an internal R&D unit, and when they are small (51 firms correspond to such a configuration –*see* Tree 1). We have, in this configuration, small foreign firms, completely dedicated to exports, and unconcerned by innovating.

The decomposition of the **process innovativeness** between PE and EE firms is analyzed in the first fourth column of Table 7. The differential gap in the rate of pro-

[6]Rahmouni et al. (2010) find that the main contrast concerns the limited role of internal R&D and the insignificant role played by foreign participation.

Variable	EE firms		NE firms	
	Product	**Process**	**Product**	**Process**
collNatOrg		No (1)		
collOtherFirms		No (3)		
ConsultTechn		No (2)		No (1)
depRD	No (1)		No (2)	No (3)
lnSales	Low (2,3,4)	Low (4)	Low (1,3,4)	Low (2)
Expected prob.	0	0.15	0	0.191; 0.255

Table 8: **Paths to the lowest propensities to innovate for EE and NE firms**. The table gives, for each class of firms and both types of innovations the combinations of characteristics that correspond to the lowest propensity to innovate. This table summarizes the most deficient cases for these two classes of firms, as they appear in the regression trees given in the Appendix. The numbers in parenthesis give the order of importance of the corresponding factors.

cess innovation between the PE and EE firms is lower, about 16.5% ($= 0.601 - 0.436$). Overall, total contribution of group differences in the average values of the independent variables account for about nearly 75% of the differential gap when the sample of PE firms is used in order to calculate the coefficients which are the basis of the decomposition. This means that difference between PE and EE firms is largely due to difference in observable characteristics rather than in the estimated coefficients and hence in the innovation behaviour. We observe that again insufficient size is one of the main factors in relative the deficiency of the EE firms, as well as sub-utilization of technical consulting agencies.

The second column of Table 8 confirms these results and also indicates that the absence of collaboration with other firms and national organisms can be aggravating factors for the EE firms (79 EE firms correspond to such a configuration, *see* also Tree 2).

The determinant of the weakness of EE firms are summarized in the following proposition:

Proposition 4 *Exclusively-exporting firms low innovativeness can be explained by the insufficient R&D effort and small size (for product innovations) or the lack of access to external technical knowledge sources and small size (for process innovations).*

A similar proposition can be established for determinants of the weakness of NE firms:

Proposition 5 *Exclusively-domestic firms low innovativeness can be explained by the insufficient R&D effort and small size (for product innovations) or the lack of access to external technical knowledge sources and small size (for process innovations).*

4.3 When do firms are able to attain higher innovativeness?

Which combinations of the factors do favour the innovativeness of firms in each subgroup. Regression trees can again be used to answer this question. Again, our discussion will be

	EE firms		PE firms		NE Firms	
Variable	**Product**	**Process**	**Product**	**Process**	**Product**	**Process**
$collNatOrg$		No (1)				
$collInterNatOrg$	Yes (2)					Yes (3)
$collOtherFirms$						
$ConsultTechn$		Yes (2)	Yes (1)	Yes (1)	Yes (2)	Yes (1)
$depRD$	Yes (1)			Yes (4)		
$lnSales$		Medium (3,4)	Medium (2,3)	Medium (2,3,5)	High (1)	High (2)
$partState$					Low (3)	
Expected prob.	0.8642	0.8095	1	1	0.7778	1

Table 9: **Paths to the highest propensities to innovate for EE and NE firms**. The table gives, for each class of firms and both types of innovations the combinations of characteristics that correspond to the highest propensity to innovate. This table summarizes the most favourable cases for these three classes of firms, as they appear in the regression trees given in the Appendix. The numbers in parenthesis give the order of importance of the corresponding factors.

focused on PE and EE firms, even if we also give the results for the NE firms. Table 9 summarizes the results of the regression trees on these configurations. We first discuss the results concerning product innovations, before turning to the conditions most favourable to process innovation.

For both types of innovations, we clearly observe that PE firms are able to attain higher innovativeness than the EE firms.

For **product innovations**, PE firms are sure to innovate when they benefit from technical consulting agencies, and when their size is not too big, while EE firms must rely on their internal R&D unit and the collaborations with international organisms to obtain their best expected propensity (0.86). This result indicates the complementarity between the internal R&D efforts and collaborations with international organisms for EE firms. Thus, the capacity to benefit from external technological knowledge sources will be explained by the construction of their absorptive capacity via the internal R&D investments. However, in all other cases their expected probabilities to innovate are inferior to 0.63 (*see* Tree 1). When the sources of innovation (for this case, internal R&D activities and collaborations) are found to be complementary, it will be less efficient to concentrate on one strategy because of the increased complexity. Managing these complementarities can be an important source for a sustainable competitive advantage (Cassiman & Veugelers 2004, Ravkin 2000). We analyses later the case of substitutability between these factors for process innovations. These two types of firms clearly have different product innovation profiles: while PE firms could benefit from national policies that would enhance the capabilities of Technical consulting agencies, the mechanisms of EE firms seem completely autonomous from these policies.

We observe more similar profiles for **process innovations**, since for both types of firms, Technical consulting agencies play an important role, completed by an intermediate firm size. But, for the EE firms, the role of Technical centers only appear if they cannot benefit from national organisms (which can, alone, favour a significant innovativeness – *see* Tree 2)). If PE firms do not access to external technical consulting (*see* bellow),

they can attain high probabilities if and only if they benefit from collaboration with international organisms or universities, indicating some substitutability between these sources. Indeed, PE firms are particularly performant in process innovations

5 Conclusions and policy recommendations

In this article we analyze the relations between export behaviour and the propensity to innovate for Tunisian firms. At the global level, we observe that partial exporters have the highest propensity to innovate because they benefit better from external knowledge sources and a heterogenous demand. Our results show that Tunisian firms do not benefit yet from their internal R&D efforts since they do not have the necessary financial resources and knowledge for undertaking innovative projects. Access to external organisms for technical assistance as well as cooperations are favorable to innovations. But this global result hides important heterogeneity between types of innovations and types of firms (partial exporters, exclusively exporting firms or non exporting ones). The existence of internal R&D capacity is in general necessary for exclusively-exporting firms, while cooperation is favorable for the majority of cases.

Table 10: Policy suggestions: fostering innovations

Product innovation	**NE:**	- Encourage access to external technical assistance and incentives private participation in capital for large firms
	PE:	- Encourage access to external technical assistance and reinforce collaborations with international organisms for firms not too big (complementarity between these activities of innovation strategy)
	EE:	- Incentives for internal R&D and collaborations with international organisms
Process innovation	**NE:**	- Encourage access to external organisms for technical assistance and reinforce cooperations with international organisms for large firms
	PE:	- Encourage access to external organisms for technical assistance or reinforce cooperations with international organisms for large firms or collaborations with universities (substitutability between these innovation strategies)
	EE:	- Reinforce cooperations with national organisms or encourage access to external technical assistance or collaborations with other firms

NE: non exporting firms, PE: partial exporting firms, EE: exclusively exporting firms

In characterizing the innovation processes, we distinguished between three types of innovative strategies that are: internal R&D efforts, collaborations and external technical assistance. We find evidence of complementarity among external sources for product innovations and of substitutability for process innovations. For Tunisian firms, the motives for cooperations are related to technical assistance and not to cost-sharing or risk-sharing. Thus, it is not surprising to find that access to assistance from external

organisms is closely related to collaborations which may differ between firms types. But, it is not the sole component in a firm's innovation strategy, and that rises the issue of complementarity among various collaborative agreements. The role of absorptive capacity of firms are less clear. Indeed, internal knowledge development should be necessary to benefit from external knowledge acquisition and R&D activities that are often essential in order to monitor and evaluate research conducted elsewhere (Rosenberg 1990).

Table 10 summarizes our suggestions for fostering innovations. For example, in the case of product innovations, collaboration of EE firms with international organisms is complementary to their internal R&D activity. Therefore, it is important to combine internal and external knowledge sources in the innovation process of these firms. This result is in line with Freeman (1991) and Veugelers & Cassiman (1999) for whom the external sources combined with internal research activities are crucial in explaining success of the innovation. However, this does not necessarily suggest a strong complementary relationship between internal R&D and external knowledge acquisition. For other types of firms we also find evidence on complementarity among other external sources (Arora & Gambardella 1990). PE firms access to external technical assistance, and their collaborations with international organisms are complementary for firms that are not too big. However, NE firms would benefit from access to external technical assistance, if public participation in capital is low. Thus, large NE firms with private participation in capital are more likely to benefit from the help of external organisms.

In the case of process innovation, innovators often relay on many different external sources of knowledge (von Hippel 1988, Reichstein & Salter 2006). Cooperations with national organisms or collaborations with other firms and access to external technical assistance are substitutable for process innovation. Access of PE firms to external organisms for technical assistance and cooperations with international organisms for large firms or collaborations with universities are also substitutes. However, for NE firms, a complementarity arises between access to external organisms and cooperations with international organisms for large NE ones.

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A Appendix

A.1 Indicators of technological development

The technology achievement index (TAI) given in Table 11 shows that Tunisia is among dynamic adopters of new technologies. The TAI aims to capture how well a country is creating and diffusing technology and building a humain skill base. It focusses on three dimensions at the country level: creating new products and process through R&D, using new and old technologies in production and consumption, and having the skills for technological learning (UNDP 2001).

Table 11: Indicators of technological development

			Low-technology exports (% of total goods exports)		**Medium-technology exports** (% of total goods exports)		**High-technology exports** (% of total goods exports)	
Country	**TAI**	**HDI**	1980	1999	1980	1999	1980	1999
Finlande	0.744	0.925	19	9	21	24	4	27
United States	0.733	0.934	.	10	.	34	.	32
Germany	0.583	0.921	16	13	48	46	12	18
France	0.535	0.924	17	14	36	37	11	22
Greece	0.437	0.881	26	26	12	13	1	5
China	0.299	0.718	.	44	.	18	.	21
Tunisia	0.255	0.714	20	52	10	16	.	3
India	0.201	0.571	33	38	10	11	3	5
Algeria	0.221	0.693	.	.	.	1	.	.
Sudan	0.071	0.439	.	2	.	.	.	.

Source: World report (UNDP 2001)
Leaders (TAI above 0.5); Potential leaders (0.35-0.49); Dynamic adopters (0.20-0.34); Marginalized (below 0.20).

A.2 Comparison of predicted probabilities

A.3 Decomposition technique

The decomposition technique developed by (Fairlie 1999, 2005). The gap in the linear dependent variable between group 1 and group 2, $\overline{Y}_1 - \overline{Y}_2$, can be decomposed into two parts:

$$\overline{Y}_1 - \overline{Y}_2 = [(\overline{X}_1 - \overline{X}_2)\widehat{\beta}_1] + [\overline{X}_2(\widehat{\beta}_1 - \widehat{\beta}_2]$$

The first component in bracket referred the gap due to the group differences in the distribution of X (characteristics). The second part represents the differences due in the behaviour processes that determine Y. Fairlie (2005) suggests a decomposition for a nonlinear equation $Y = F(X\widehat{\beta})$.

A.4 Regression trees

Table 12: Comparison of predicted probabilities: WMW test

Product innovation		
H_0: $predinnov(EE) = predinnov(PE)$		
z-stat	p-value	probability
-7.453	0.000	$P\{predinnov(EE) > predinnov(PE)\} = 0.288$
H_0: $predinnov(NE) = predinnov(PE)$		
z-stat	p-value	probability
-5.307	0.000	$P\{predinnov(NE) > predinnov(PE)\} = 0.327$
H_0: $predinnov(NE) = predinnov(EE)$		
z-stat	p-value	probability
0.208	0.835	$P\{predinnov(NE) > predinnov(EE)\} = 0.507$
Process innovation		
H_0: $predinnov(EE) = predinnov(PE)$		
z-stat	p-value	probability
-7.444	0.000	$P\{predinnov(EE) > predinnov(PE)\} = 0.288$
H_0: $predinnov(NE) = predinnov(PE)$		
z-stat	p-value	probability
-4.851	0.000	$P\{predinnov(NE) > predinnov(PE)\} = 0.342$
H_0: $predinnov(NE) = predinnov(EE)$		
z-stat	p-value	probability
1.138	0.255	$P\{predinnov(NE) > predinnov(EE)\} = 0.537$

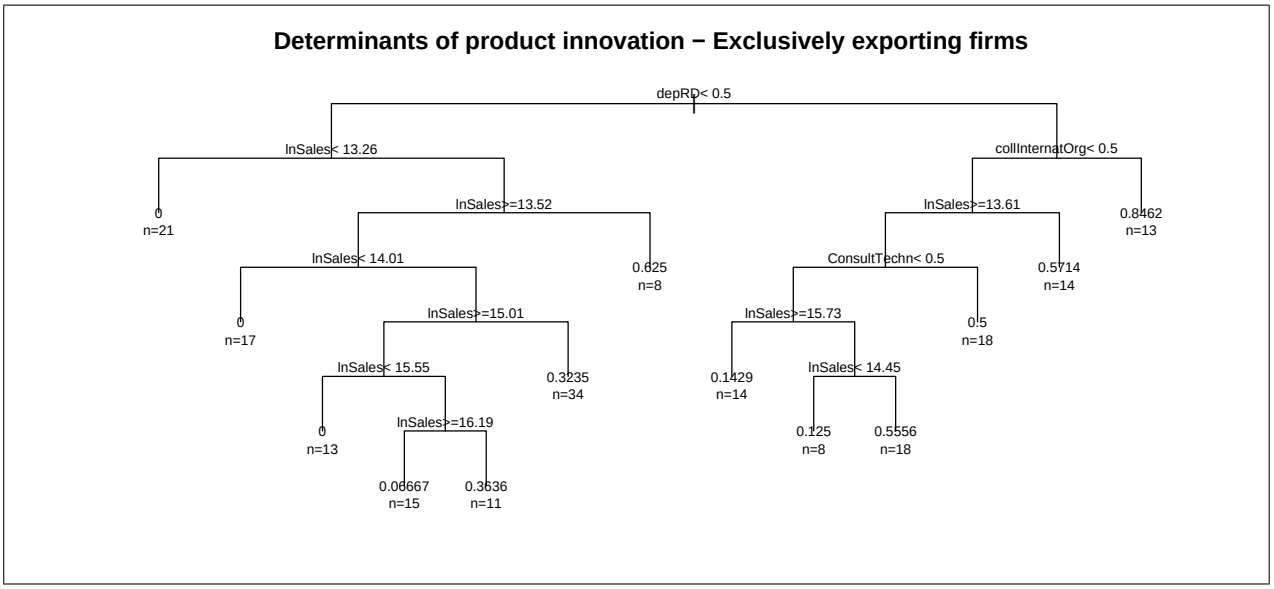

Figure 1: Determinants of product innovations. Exclusive exporters ($cp = 0.01$).

	Product Innovation				Process Innovation			
	PE vs EE		PE vs NE		PE vs EE		PE vs NE	
Reference Group	**PE**	**EE**	**PE**	**NE**	**PE**	**EE**	**PE**	**NE**
P(innovate=1/Group)	0.563	0.304	0.563	0.341	0.601	0.436	0.601	0.429
Differential gap	0.259	-0.259	0.221	-0.221	0.165	-0.165	0.172	-0.172
characteristics effects	0.135	-0.139	0.145	-0.104	0.123	-0.140	0.116	-0.129
Contribution in percent	52.32%	53.79%	65.54%	47.01%	74.76%	85.22%	67.44%	74.74%
Residual effects	0.123	-0.119	0.076	-0.117	0.042	-0.024	0.056	-0.044
Contribution in percent	47.68%	46.21%	34.46%	52.99%	25.24%	14.78%	32.56%	25.26%
Detailed decomposition								
depRD	0.012	-0.064	0.009	-0.033	0.022	-0.025	0.017	-0.003
% of the gap	4.49%	24.83%	4.25%	14.74%	13.48%	15.00%	10.09%	1.80%
lnSales	0.022	0.003	0.010	-0.032	0.024	-0.067	0.011	-0.039
% of the gap	8.35%	-1.08%	4.29%	14.55%	14.57%	40.38%	6.26%	22.86%
partState	-0.015	0.000	0.050	-0.042	-0.011	0.012	0.048	-0.022
% of the gap	-5.68%	-0.08%	22.78%	19.12%	-6.68%	-7.10%	27.79%	12.59%
collUniv	0.012	-0.027	0.002	0.009	0.025	-0.014	0.000	-0.002
% of the gap	4.72%	10.36%	0.99%	-4.02%	15.12%	8.44%	-0.06%	1.04%
CollRecCent	-0.005	0.001	-0.001	0.000	-0.006	0.004	0.005	0.004
% of the gap	-1.74%	-0.39%	-0.45%	0.18%	-3.34%	-2.13%	2.78%	-2.03%
collLabUnit	0.007	0.006	0.004	0.020	-0.014	0.024	-0.004	0.002
% of the gap	2.75%	-2.24%	1.99%	-9.00%	-8.50%	-14.76%	-2.15%	-1.22%
collNatOrg	0.003	-0.001	0.003	-0.002	0.003	-0.007	0.002	-0.002
% of the gap	0.97%	0.54%	1.49%	0.95%	1.64%	4.49%	1.33%	0.99%
collInternatOrg	0.023	-0.023	0.007	0.000	0.015	-0.007	0.000	0.000
% of the gap	8.74%	9.05%	3.30%	-0.02%	8.80%	4.01%	-0.12%	0.17%
collOtherFirms	0.002	-0.001	0.006	-0.001	-0.001	-0.005	-0.001	-0.002
% of the gap	0.81%	0.39%	2.89%	0.23%	-0.49%	2.73%	-0.81%	0.99%
ConsultTechn	0.075	-0.032	0.052	-0.022	0.066	-0.056	0.040	-0.063
% of the gap	29.04%	12.49%	23.64%	10.08%	40.14%	34.25%	23.09%	36.25%

Decomposition using 100 replications (Fairlie 2005).

Table 13: Decomposition analysis of the consequences of export behaviour on innovation propensity

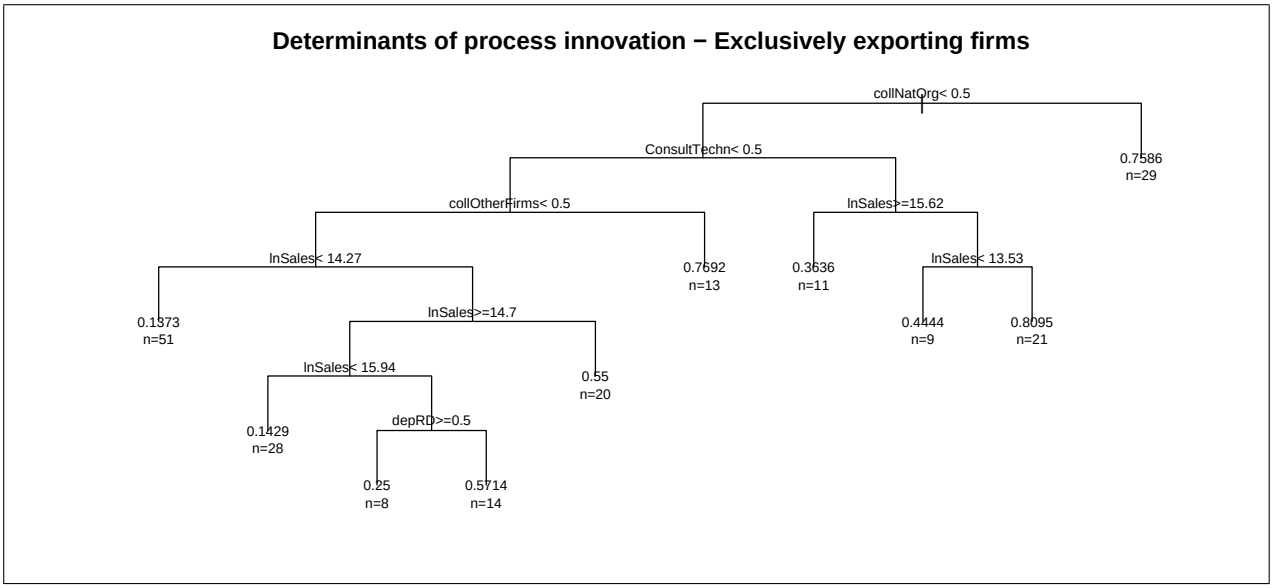

Figure 2: Determinants of process innovations. Exclusive exporters ($cp = 0.01$).

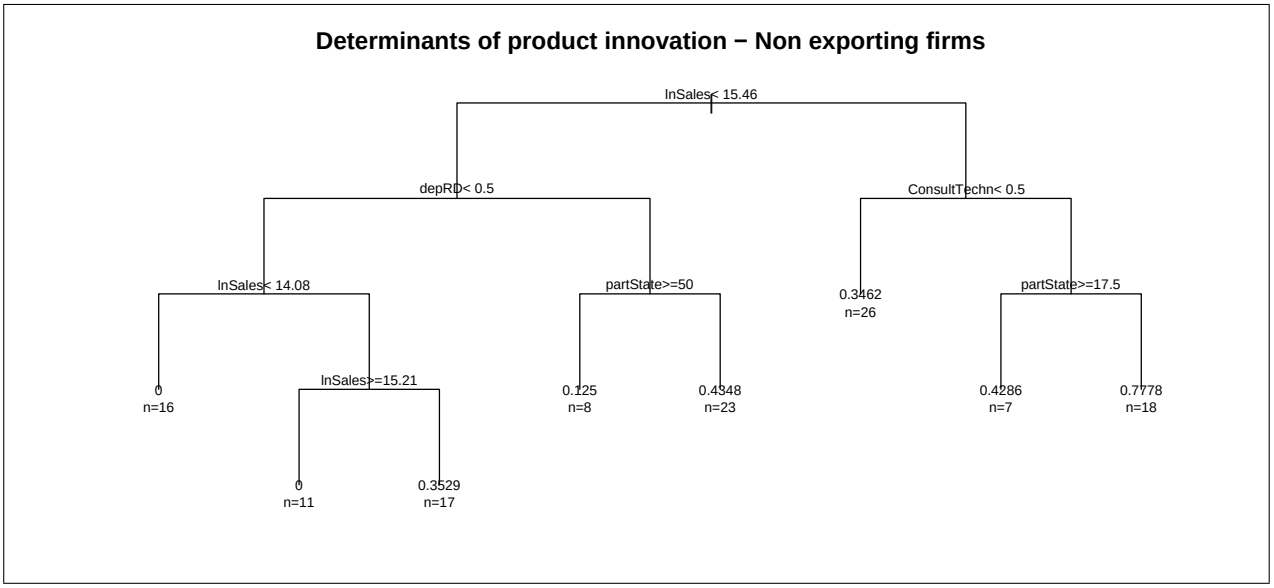

Figure 3: Determinants of product innovations. Nonexporters ($cp = 0.01$).

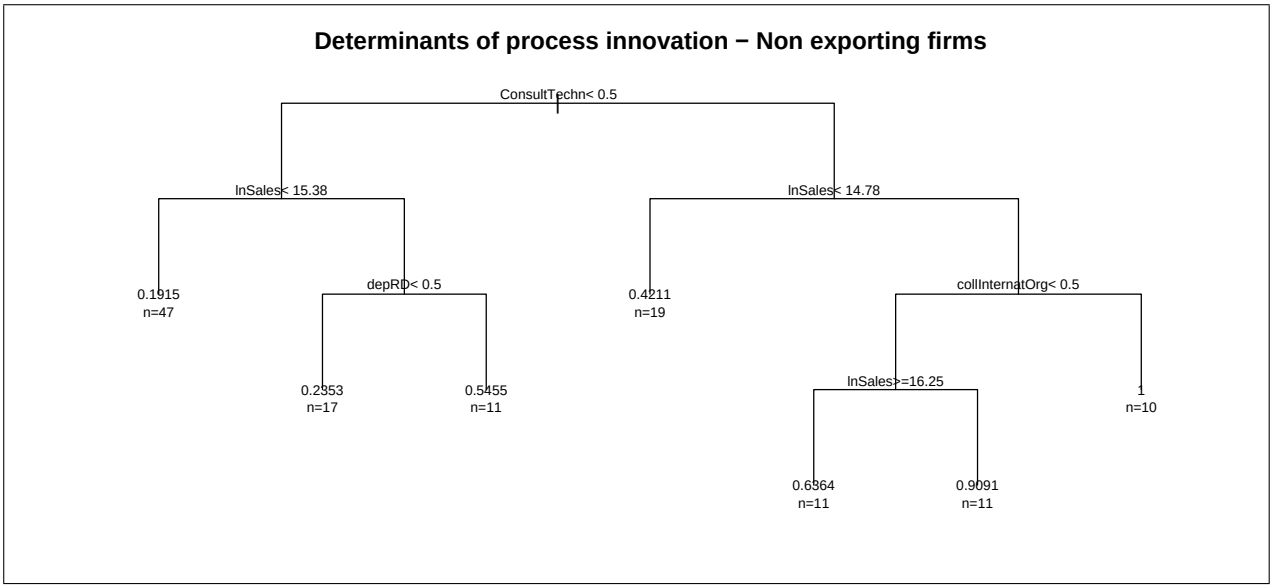

Figure 4: Determinants of process innovations. Nonexporters ($cp = 0.01$).

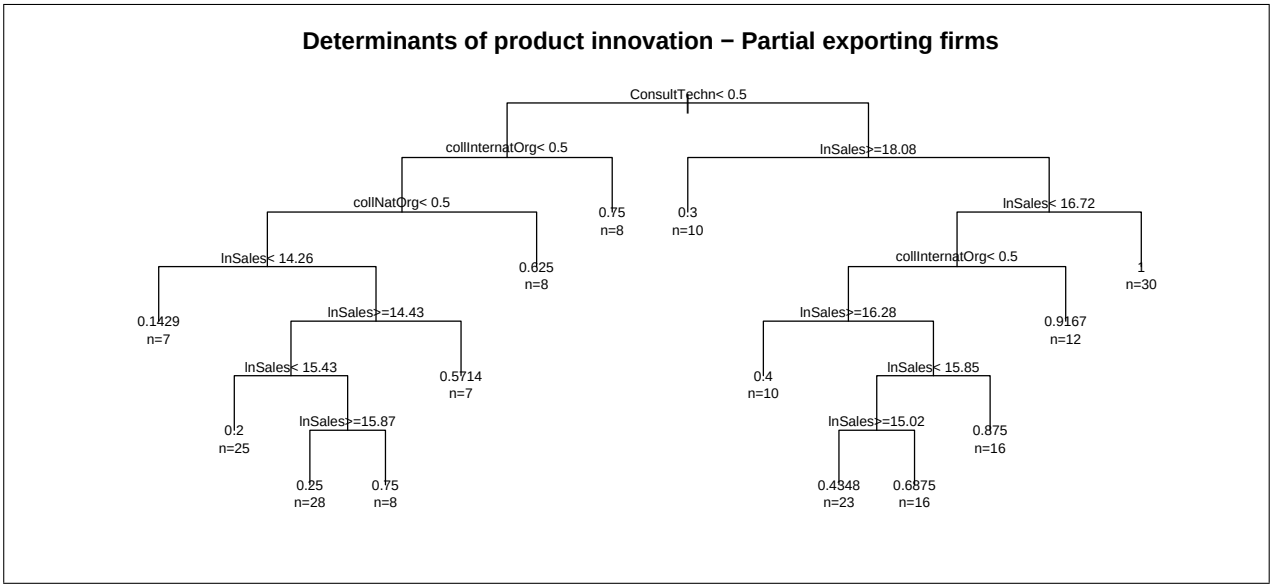

Figure 5: Determinants of product innovations. Partial exporters ($cp = 0.01$).

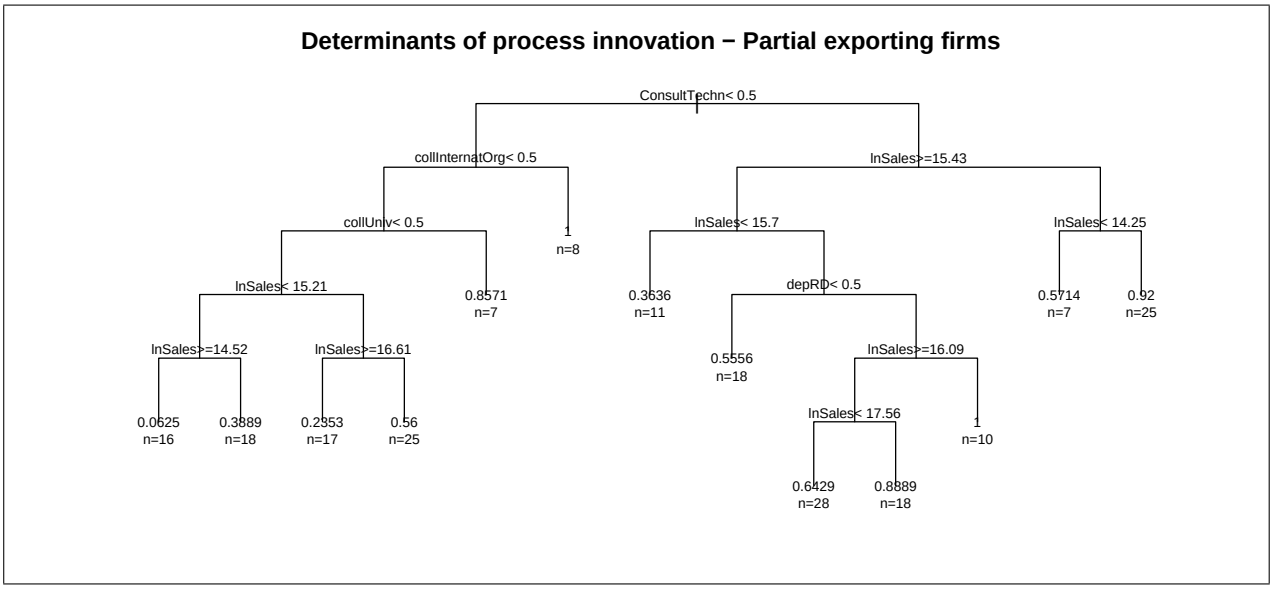

Figure 6: Determinants of process innovations. Partial exporters ($cp = 0.01$).